Exploring Mars: Following the Water

and the Next Decade

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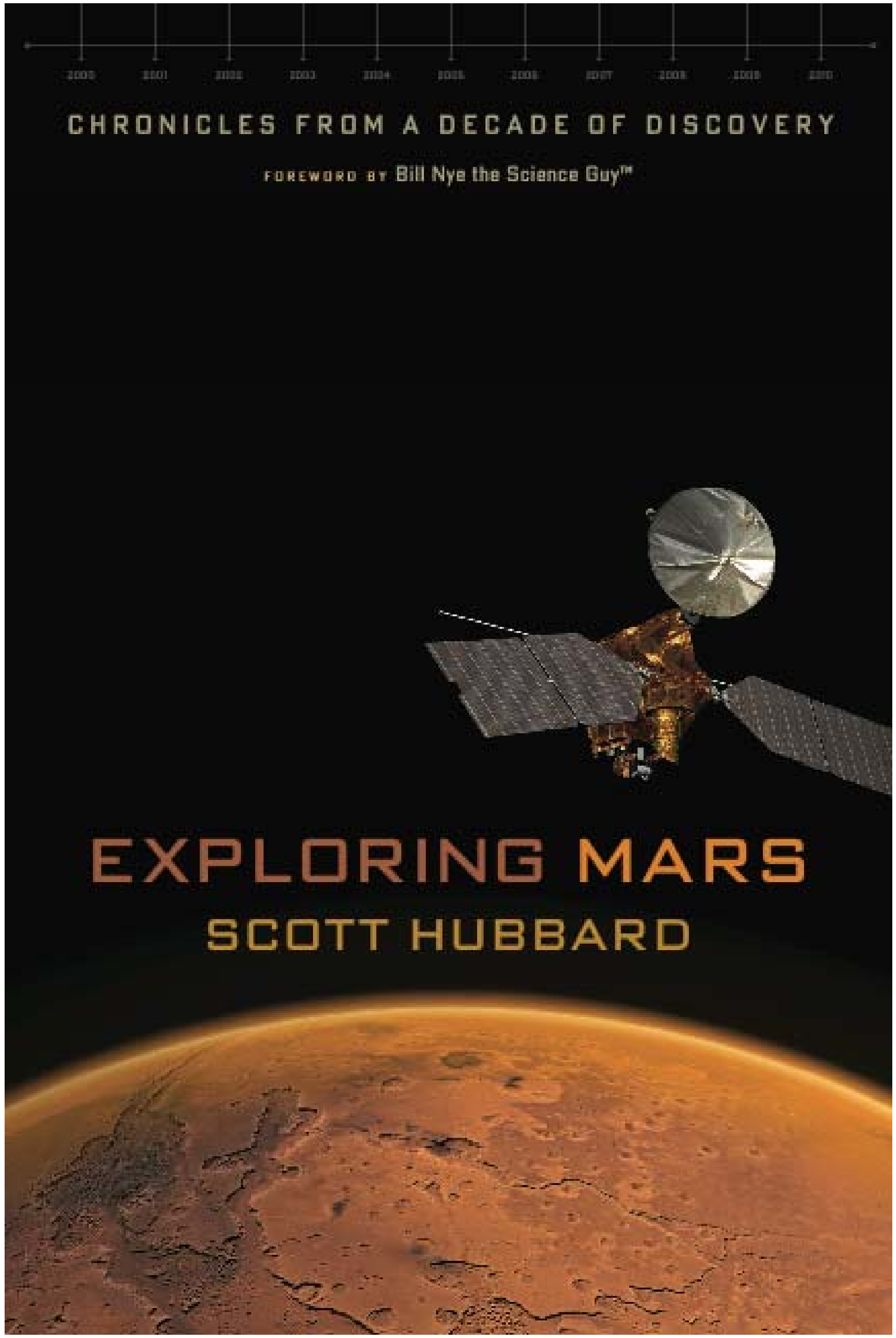
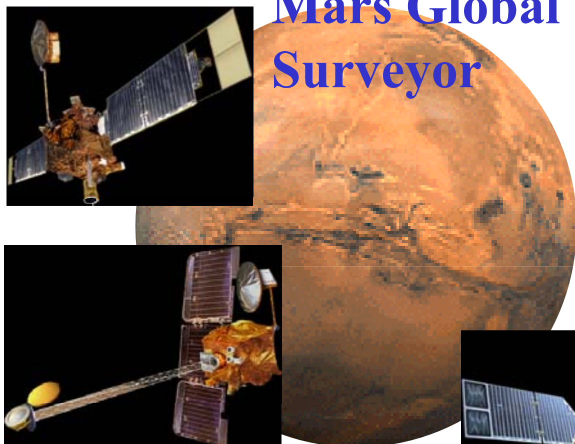
Solar System Exploration at 50
October 26, 2012


CHRONICLES FROM A DECADE OF DISCOVERY
FOREWORD BY Bill Nye the Science Guy™
EXPLORING MARS
SCOTT HUBBARD

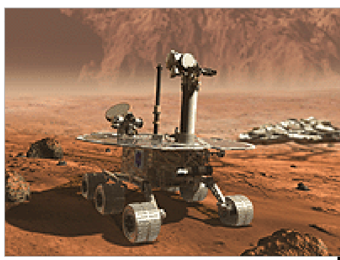
Today's Robotic Mars Exploration Program



Mars Global Surveyor

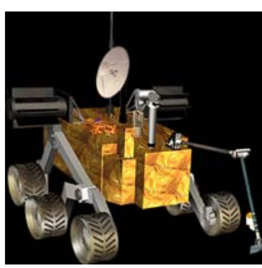
Mars Odyssey

Mars Reconnaissance Orbiter



Mars Exploration Rovers

Phoenix Scout



Mars Science Laboratory

Redefined in October 2000 after twin failures in 1999

A science-driven effort to characterize and understand Mars as a dynamic system, including its present and past environment, climate cycles, geology, and biological potential.

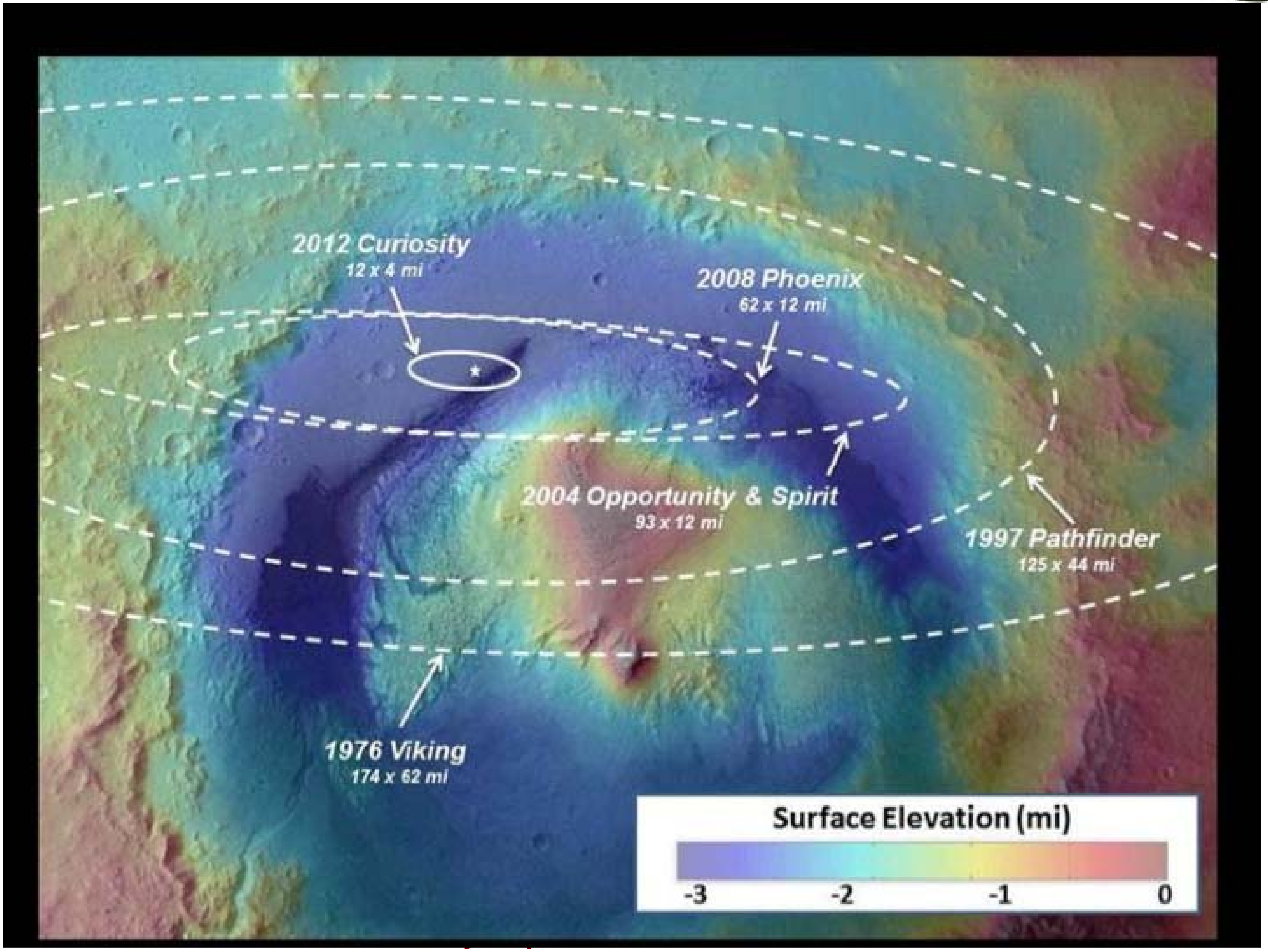
Central among the questions to be asked is…

"Did life ever arise on Mars?"

The science strategy is known as "Follow the Water."

Mission queue also prepared for following decade – Sample Return

Example: Landing Accuracy Improvement



Where are our discoveries leading us?

- Ancient life—potential has increased
  - **Lots of ancient liquid water, surface and ground**
  - **Past geological environments that have reasonable potential to have preserved the evidence of life, had it existed.**
  - **Understanding variations in habitability potential is proving to be an effective search strategy**
  - **SUMMARY: We have a means to prioritize candidate sites, and reason to believe that the evidence we are seeking may be preserved and is within reach of our exploration systems.**
- Modern life—possible
  - **Evidence of modern liquid water at surface is equivocal—probable liquid water in deep subsurface**
  - **SUMMARY: We have not yet identified high-potential surface sites, and the deep subsurface is not yet within our reach. <u>But, methane may be a critically important clue to subsurface biosphere</u>**
- Mars is more diverse than previously thought

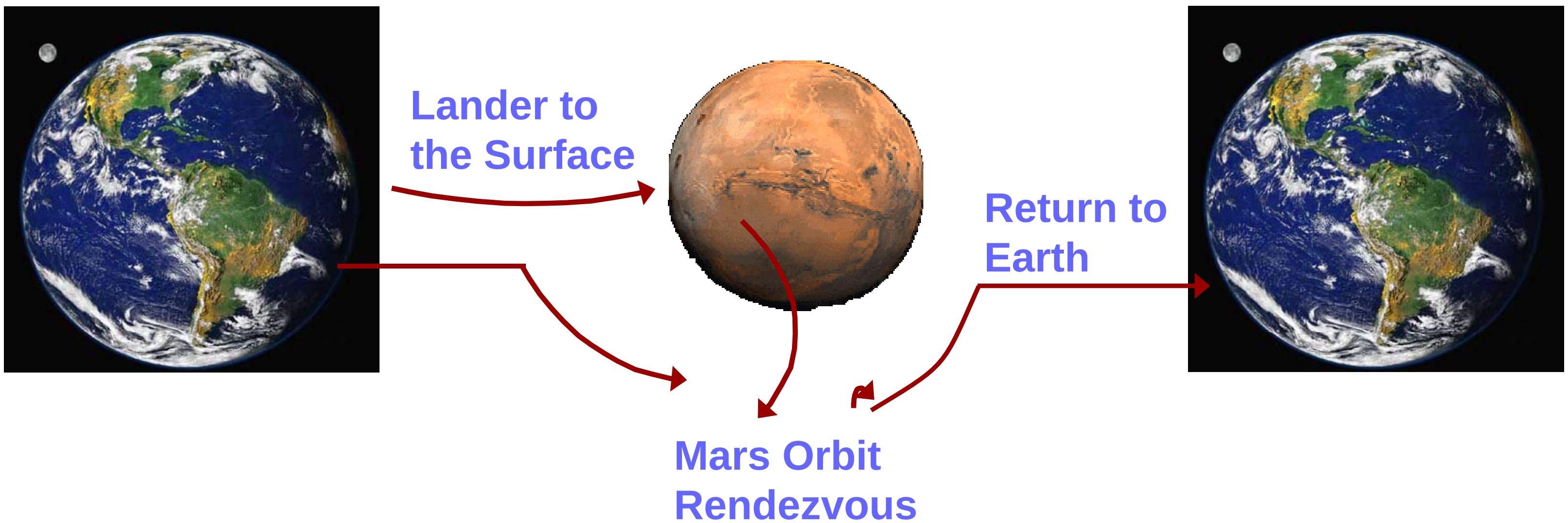
From:

"Follow the Water"

To:

"Seek Signs of Life"

2013-2022 Recommended by the NRC Decadal Survey: Mars Sample Return



<u>Why:</u>

- Next logical step – most science return for the investment
- Samples can be analyzed by multiple labs
- Investigations by 100's of researchers
- Advanced instrument utilized that is too large, complex or recent for space hardware
- Alternate measurement routes can be followed

Rover Concepts Comparison (2)

Rover C

- Solar MSL-based system
- Build on successful MSL design heritage.

Advantages

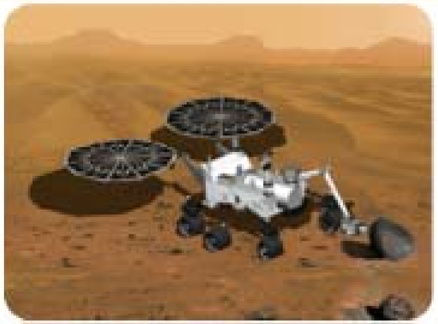
- Robust to payload growth
- Substantial HEO/STP payload opportunity
- Best mobility range/life/mission return
- Substantial redundancy
- High EDL heritage
- Feed forward applicability to large MSR / MAV missions

Challenges

- High launch vehicle costs (Atlas)

Cost Estimates

- Internal $1.0B
- Aerospace ICE $1.1B
- Aerospace CATE $1.3B
- LV (A5) $0.32B ('18) / $0.40B ('20)
- **Phase A-D ~$1.3 - 1.7B**



Rover D

- MSL-based system with integrated MAV
- Build on successful MSL heritage.

Advantages

- Provides capable surface science platform
- Supports agency MAV demonstration / return capability
- Best mobility range/life/mission return
- Substantial redundancy
- High EDL heritage
- Can be coupled w/ return orbiter for lowest MSR cost

Challenges

- Rover mechanical mods; MAV development; and LV costs

Cost Estimates (STILL UNDER DEVELOPMENT)

- Internal ~$1.4B estimate only
- Aerospace ICE N/A
- Aerospace CATE N/A
- LV (A5) $0.32B ('18) / $0.40B ('20)
- **Phase A-D TBD**

Mars Sample Return Challenges: Status

- **Science**
  - **–Where and how to go? (Site selection possible with emerging data (NRC 2007); MSL has demonstrated accurate landing)**
- **Major Technology and Engineering Challenges addressed for most scenarios**
  - **–Orbital autonomous rendezvous, docking and sample transfer: (Orbital Express - DARPA Project - has provided useful experience**
  - **–Planetary protection and the Sample Receiving Facility: (Industry Studies provided baseline designs, cost estimates need updating)**
  - **–Sample Return Vehicle: (Risk largely retired with Genesis and Stardust)**
  - **–Mars Ascent Vehicle: (Probably requires most engineering development, but new technologies are promising)**
- **Cost:**
  - **–MPPG study demonstrates that a caching rover to begin the MSR campaign can be developed for $1.3 -1.7B << than a Flagship!**

Given appropriate technology and instrument investment, a credible Mars Sample Return Mission can now be planned

STANFORD
ENGINEERING

Backup

Where are we today on site/sample selection?

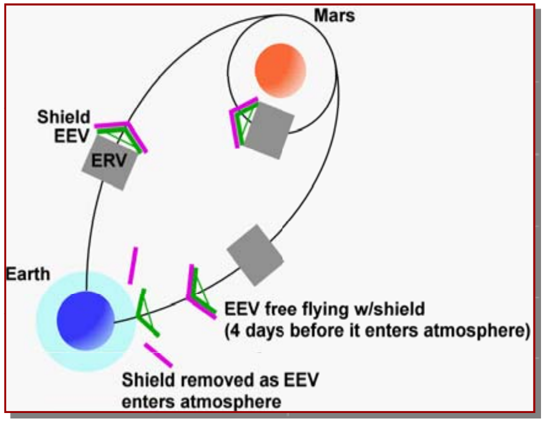
- **NRC Report* states that data collected from this decade (2000-2010) of missions can lead to a well-selected sample**
  - –*Finding.* Identification of appropriate landing sites for detailed analysis (whether in situ or by sample return) can be done with the data sets now available or imminently available from currently active missions.
  - –*Recommendation.* Future surface missions must have the capability to visit most of the Martian surface, including Noachian terrains and polar and high-latitude areas, and to access the subsurface.
  - –*Recommendation.* Selection of samples for analysis (either in situ or of samples returned from Mars to Earth) should emphasize those having the best chance of retaining biosignatures.

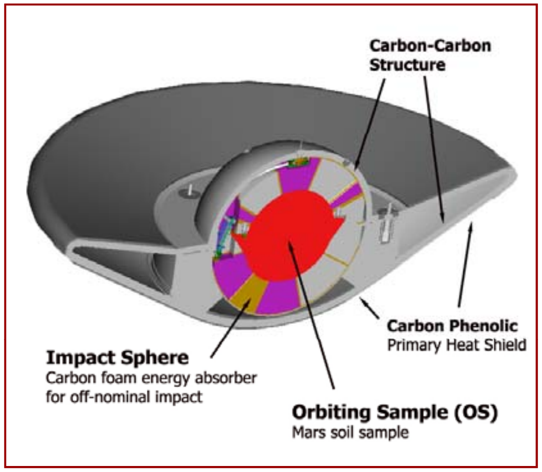
*An Astrobiology Strategy for the Exploration of Mars

Scientists are much more prepared to select a sample

Challenges and Status of the MSR Sample Return Vehicle

- **Challenge: Planetary Protection Requirement during Earth Entry ≈1X 10E-6**
- **Mission Scenario and SRV design Challenges**
  - –**Micrometeorite Impact Protection Technology**
  - –**Thermal Protection System Technology**
  - –**Flight Dynamics**
  - –**Vehicle Sterilization Methods**
- **Status: We have learned much from Stardust and Genesis**
  - –**Heritage Carbon-Phenolic TPS baselined**
  - –**Carbon-Carbon Structure to be verified**
  - –**EEV Shape and Direct Impact needs some effort**
  - –**Sterilization of seals not complete**
- **Need: Integrated Design Flight Demonstration**





Mars Sample Receiving Facility

Engineering Design Challenge

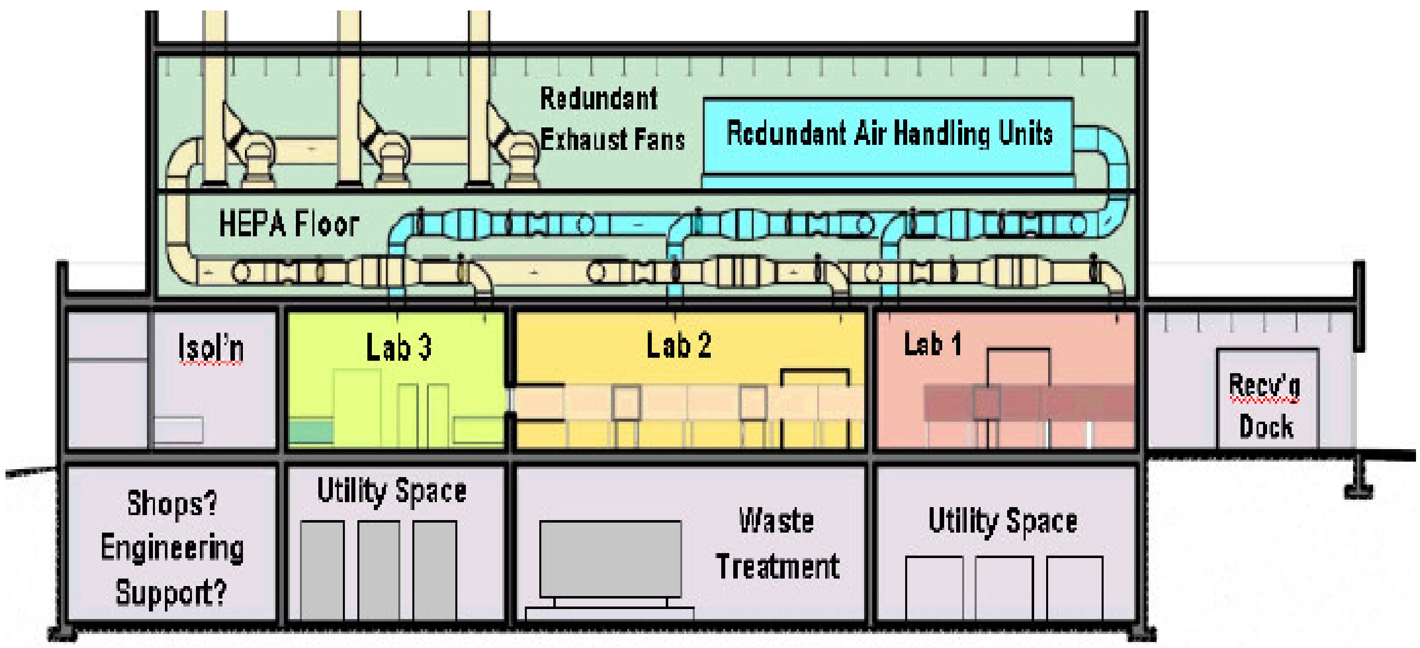
- Containment equivalent to that of BSL-4 (low pressure)
- Clean-room characteristics for sample purity (high pressure)

⇒How to integrate these?

Some Major Open questions

- What process would be used to select the site - will 8-10 years be required to locate and build?
- How would the science community be given access to the samples?
- What tests would need to be done on the samples in order to be able to certify their safety?

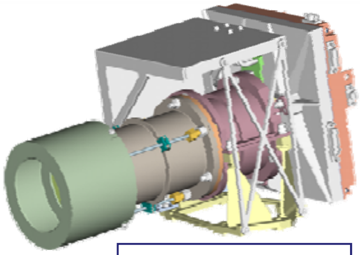
Current Status:
3 industry studies in 2003/04
Planning is idle.



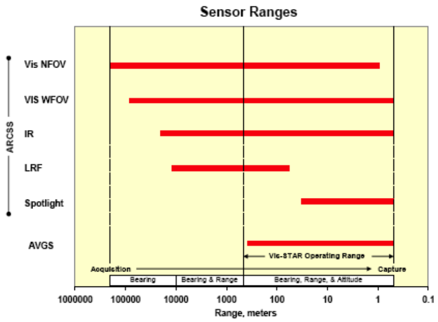
Mars Sample Return Rendezvous Challenge

- **Mars Sample Return Design Highlights (proposed architecture):**
  - **A Mars Ascent Vehicle (MAV) launches a sample to Orbiting Sample sphere (OS) into low Mars orbit (500 km)**
- **Mars Sample Return Rendezvous Challenge:**
  - **Long range (>5000 km) optical and RF beacon detection of the 16 cm OS by the SRV.**
  - **Precision autonomous terminal rendezvous and capture of the OS by the SRV without target (OS) rendezvous aids.**
- **Mars Sample Return Rendezvous Technology Status:**
  - **Mars Reconnaissance Orbiter (MRO) has long-range passive optical navigation sensor. Long range performance in Mars orbit is TBD.**
  - **Orbital Express (DARPA) has developed and flight tested autonomous rendezvous, sensors, flight software and capture techniques in Earth orbit (demo completed July 2007):**

MSR MAV Launch



MRO Optical Nav Camera



Orbital Express Tracking Sensors (Weismuller, AAS, 2006, AAS 06-016)

Mars Ascent Vehicle

- **Proposed Requirement:**
  - **–MAV launched from Earth as payload**
  - **–Dormant during cruise (7-9 months)**
  - **–MAV successfully landed on Mars (with sample retrieval rover)**
  - **–MAV dormant during 3-6 months with diurnal temp variance of -100 C to +20 C**
  - **–MAV successfully launch 5 kg to ~500km Mars orbit to rendezvous with Sample Return Vehicle**

- **Current Status:**
  - **–3 Industry Studies in 2001**
  - **–Differing 2-stage approaches; all acknowledged challenge of mission duration and environmental storage.**

Rover Concepts Comparison (1)

Rover A

- MER-based system w/ guided entry addition
- Build on successful MER design heritage.

Advantages

- Heritage MER mechanical structures and EDL systems
- High EDL heritage
- Feed forward applicability to small surface missions
- Low recurring costs
- Low launch vehicle costs (Falcon 9 v1.1)

Challenges

- Very limited payload/volume margin

Costs Estimates

Internal	$1.1B
Aerospace ICE	$1.0B
Aerospace CATE	$1.0B
LV (F9)	$0.16B ('18) / $0.19B ('20)
Phase A-D	**~$1.1 - 1.3B**

Rover B

- Scaled MER-based system w/ guided entry addition
- Build on successful MER architectural heritage.

Advantages

- Robust to inheritance assumptions (new systems)
- Feed forward applicability to small/mid surface missions
- Low recurring costs
- Low launch vehicle costs (Falcon 9 v1.1)

Challenges

- Requires new airbag & touchdown system development

Costs Estimates

Internal	$1.2B
Aerospace ICE	$1.1B
Aerospace CATE	$1.1B
LV (F9)	$0.16B ('18) / $0.19B ('20)
Phase A-D	**~$1.3 - 1.4B**